Processes Affecting Exchange of Mud Between Tidal Channels and Flats

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LONG-TERM GOALS

The goal of our Tidal Flats research is to expand our understanding of the erosional and depositional processes that lead to exchange of mud between tidal channels and tidal flats. We also investigate the effect of sediment texture on sediment strength.

OBJECTIVES

Our research on Tidal Flats DRI had three primary objectives:

1. Improve understanding of how turbulence and sediment concentration affect the size-dependent depositional flux of sediment to the seabed on tidal flats. Based on our observations during the project, this objective has been broadened to include the effect of rainfall and runoff.
2. Improve understanding of how sediment texture and sorting in the seabed affect the size-dependent erosional flux from the seabed on tidal flats.
3. Link our understanding of erosional and depositional sorting to spatial and temporal patterns of grain size on tidal flats.

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APPROACH

We have collected three types of data at the southern end of Willapa Bay, WA. We have conducted regional grain size surveys along a transect extending from the muddier southeast portion of Shoalwater Bay near Round Island to the sandier northwest portion (Figure 1). We have measured suspended particle properties with a set of instrument pods deployed simultaneously in a secondary tidal channel and the adjacent flat (Figure 2). The instruments carried on the pods were 2 LISST-100X laser particle sizers, 2 digital floc cameras (DFCs), a digital video settling column (DVC), and a McLane in situ water transfer system. We also deployed Aquadopp acoustic Doppler current meters with each set of pods. To examine erodibility and erosional sorting, we have collected and eroded sediment cores with a Gust erosion chamber.

Hill, Law, and Milligan collaborate closely on all aspects of this project. John Newgard (Dal) and Vanessa Page (BIO) provide support in the lab and field.

We collaborate closely with several other PIs in the tidal flats group. We share cores and erosion data with Pat Wiberg (UVA). We work closely with Rob Wheatcroft (OSU) on sample collection, and we share data on sediment properties. We provide Bernie Boudreau and Bruce Johnson with cores and grain size data. We coordinate our sampling plans with Chuck Nittrouer and Andrea Ogston (UW).
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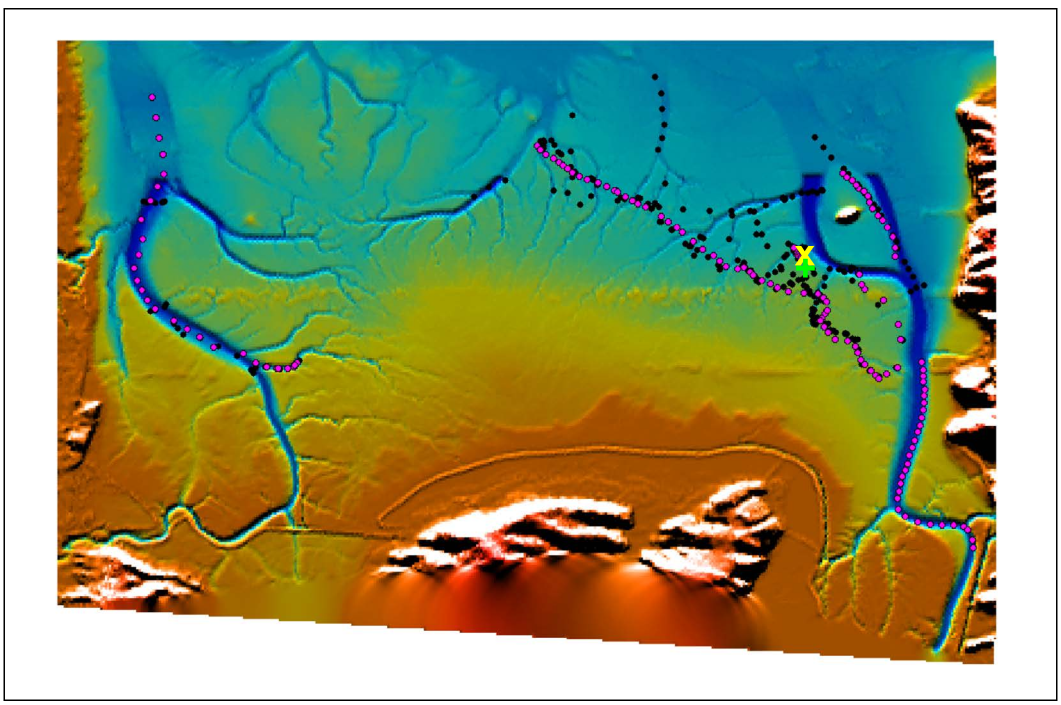

Figure 1: Location map for Willapa Bay Tidal Flats instrumentation and sediment survey. The deployment locations of our suites of optical and acoustic instruments on the tidal flat and adjacent channel are indicated by the yellow X and green plus. The black and pink symbols show analyzed grain size sample locations. Color indicates flat elevation obtained from a 2002 NOAA Lidar survey. Image is ~4km wide.

WORK COMPLETED

Four major tasks were completed during the report period:

1. Development of new tidal flat data analysis techniques;
2. Detailed analysis of March 2010 data;
3. Publication of two papers to the Tidal Flats Special Volume; and,
4. Preparation of a paper on controls on floc size and suspended mass, to be submitted November 2012.

Figure 2. Instruments on the Willapa Bay tidal flat. From left to right, Digital Settling Velocity Camera (DVC), LISST 100x, Digital Floc Camera (DFC), and 2 Nortek Aquadopps.

RESULTS

Several results have emerged from our work.

- Significant peaks in flow speed occur as the flood tide invades the flats. It is this "pulse" that controls the delivery of mobile channel sediments to the flats. The pulse intensity rises and falls with the spring-neap cycle.
- The availability of mobile sediments in the channels increases with time since the previous neap tide, when consolidation of low-strength, high-water-content mud occurs.
- Moderate river discharge events can cause marked increases in floc concentration (mass and volume), size, and floc fraction during pulses.
- The relationship between pulse SPM and high-water floc size and concentration is weaker than previously thought. Rapid settling following the pulse sequesters suspended flocs on the bed, presumably until they are resuspended by high ebb-pulse currents and wave shear stresses. The

remaining “background” concentration of small flocs varies little throughout the spring-neap cycle.

- Suspended volume at high water increases with each tidal cycle following neap tide, despite relatively insignificant changes in high-water suspended mass. Floc density at high water also falls with time since neap tide. The divergent behavior of mass and volume is attributed to flocculation at higher water.
- High-water floc size is determined by the flocculation rate and turbulence. Flocculation rate increases with time since neap tide as component flocs become stronger and larger with exposure to serial tidal cycles. Flocculation occurs to a greater extent during deeper tidal cycles, attributable to greater durations of lower turbulence as a result of reduced wave penetration to the seabed.
- Floc Fraction values are higher with lower elevations, in generally higher porosity finer grain sediments are found on tidal banks and in tidal channels as compared to the tidal flats.
- Erosional sorting of sediments are comparable to the results seen in ONR-funded Euro-STRATAForm (Gulf of Lions) where sediments with >7.5% clay (<4um) behave cohesively.

IMPACT/APPLICATION

Variability in seabed properties represents a major concern for safe and efficient travel across tidal flats. People and equipment can sink deeply into muds with large water contents and fine grain size, making travel difficult and potentially dangerous. The link between seabed properties and “trafficability” motivates efforts to understand the formation of low-strength, high-water-content muds so that models that predict the locations of such deposits can be developed. Our work suggests that in winter, high-water-content muds will be found in and on the flanks of secondary channels, particularly during waning spring tides and following river discharge events when flocculation can lead to rapid deposition of muds to the seabed. High-water-content muds are less common in summer, likely due to limited sediment supply associated with low rainfall and the associated runoff.

RELATED WORK

Results from the in-situ measurement of particle size, beam attenuation (c_p), and settling velocity are being applied to the ONR funded Ocean Optics OASIS project. The two LISSTs used in this project were purchased with Canadian funds, one from a project on oil-mineral aggregation (NSERC, Hill) and one on particle transport away from finfish aquaculture sites (DFO, Law).

Hill and Law are conducting a study similar to the Willapa Bay study on a tidal flat in the macro-tidal Minas Basin of the Bay of Fundy. This work is supported by Nova Scotia through Offshore Environmental and Energy Research (OEER, now OERA). The results from the Fundy research will determine the extent to which Willapa results are applicable to other environments.

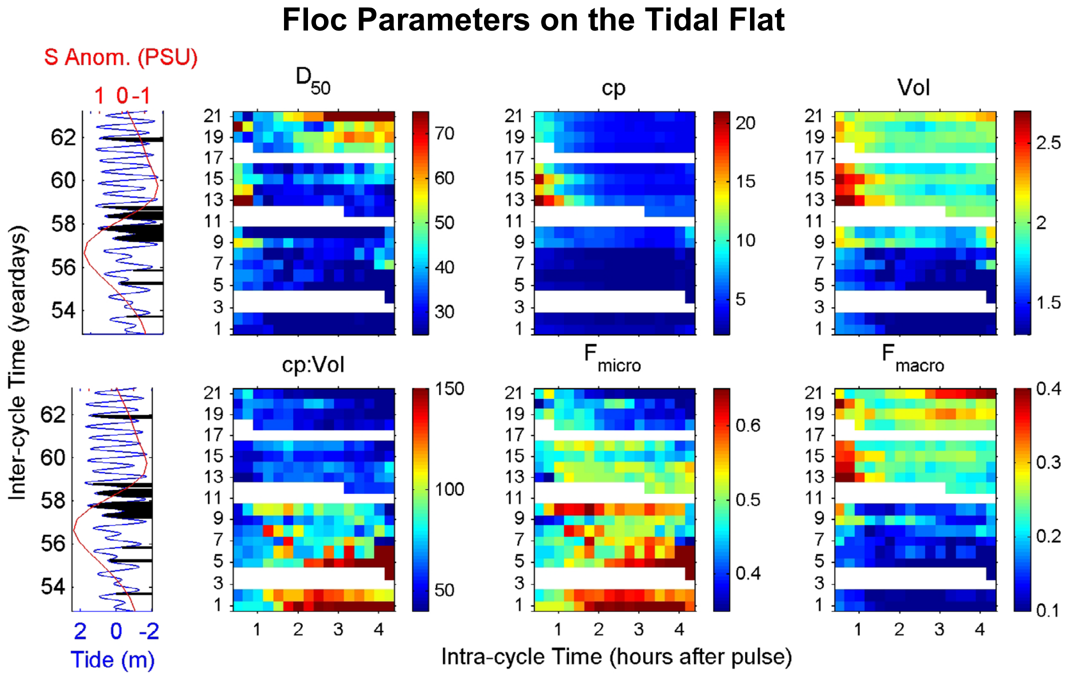

Figure 3. Floc parameters measured over the tidal flat during the Feb-Mar 2010 deployment. Parameters are given above their respective false-color plots. Intra-cycle time is on the x-axes, in hours since the peak channel pulse, and inter-cycle time is on the y-axes and is given by tidal cycle number (approx. 2 cycles per day). On the far left-hand side, time series are provided for the salinity anomaly, in red, and tidal height, in blue. Low salinity anomalies are caused by significant freshwater inflow. Windy periods are indicated by black shading of the tide data. D50 (µm) is the median particle diameter. Cp (m^{-1}) is the optical beam attenuation measured with the LISST and is proportional to mass. Vol (ppm) is the suspended particulate volume. Cp:Vol (m^{-1}) serves as a proxy for floc density. Fmicro and Fmacro are the fractions of the total particulate mass contained in microflocs (<36 µm) and macroflocs (>133 µm) respectively. The data indicate that suspended mass above the flat was greatest during the pulse, when the maximum effect of river discharge on the salinity and, presumably, the sediment concentration in the channels, was observed at the site. Though floc size was also elevated during the pulse, it increased during rising water, independent of the mass. High-water floc size increased to a maximum that occurred during the last cycle of the experiment. The observed behaviors are due to rapid settling after the flood pulse and particle aggregation during rising and high water.

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